

Shigeo Yoshida*





- Handheld Pin-based Shape Display for Haptic Rendering in Virtual Reality
 - Hideaki Kuzuoka Yuqian Sun*







*The first two authors contributed equally to this work.



PoCoPo is a *first* handheld pin-based shape display that can render various 2.5D shapes in hand.

PoCoPo

Motivation

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Reproduction of shape sensation in VR is still under development

UL.





VR Device for Shape Rendering with Haptic Feedback





[1] Inrak Choi, et al. CLAW: A Multifunctional Handheld Haptic Controller for Grasping, Touching, and Triggering in Virtual Reality. CHI '18. [2] Xiaochi Gu, et al. Dexmo: An Inexpensive and Lightweight Mechanical Exoskeleton for Motion Capture and Force Feedback in VR. CHI '16. [3] Kouta Minamizawa, et al. Ghostglove: Haptic existence of the virtual world. ACM SIGGRAPH 2008 New Tech Demos.





VR Device for Shape Rendering with Haptic Feedback

Simple mechanisms to provide force feedback to hands but... Lack of skin contact sensation

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Pin-based Shape Display



[1] Hiroo Iwata, et al. Project FEELEX: adding haptic surface to graphics. In Proceedings of the 28th annual conference on Computer graphics and interactive techniques. 2001. [2] Sean Follmer, et al. inFORM: Dynamic Physical Affordances and Constraints Through Shape and Object Actuation. UIST '13. [3] Alexa F. Siu, et al. shapeShift: 2D Spatial Manipulation and Self-Actuation of Tabletop Shape Displays for Tangible and Haptic Interaction. CHI '18.



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Haptic Edge Display^[1]

1.5D shape

free-form

static/dynamic shape

backdrivable

[1] Sungjune Jang, et al. Haptic Edge Display for Mobile Tactile Interaction. CHI '16.

[2] Shan-Yuan Teng, et al. PuPoP: Pop-up Prop on Palm for Virtual Reality. UIST '18.

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ΡοCoPo

2.5D shape

free-form

static/dynamic shape

non-backdrivable





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non-backdrivable

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2.5D shape

free-form

static/dynamic shape

PuPoP^[2]

3D shape

pre-defined (subject to attached airbag)

static shape



PoCoPo

Implementation

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Challenge:

How to make a pin-based shape display into a handheld size?



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How to make a pin-based shape display into a handheld size?



Lead screw linear actuator^[1]

mechanism gets larger along motor direction

[1] Alexa F. Siu, et al. shapeShift: 2D Spatial Manipulation and Self-Actuation of Tabletop Shape Displays for Tangible and Haptic Interaction. CHI '18. [2] Lining Yao, et al. PneUI: pneumatically actuated soft composite materials for shape changing interfaces. UIST '13. [3] Ryo Suzuki, et al. ShapeBots: Shape-changing Swarm Robots. UIST '19.

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Pneumatic actuator^[2] less mobility



Reel-based linear actuator^[3] insufficient power



Challenge:

How to make a pin-based shape display into a handheld size?



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Worm-gear based lead screw linear actuator



PoCoPo Implementation



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PoCoPo Implementation



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Number of pins	36
(2 sides)	

Pin width (mm)	8.7
Pin pitch (mm)	9.5
Travel resolution (mm)	0.5
Max speed (mm/s)	4.67
Output force (N)	2.5



PoCoPo | Implementation



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PoCoPo Implementation

Pin

Worm Wheel w/ Lead Screw (Reflective pattern)

Spacer w/ Photomicrosensor











3 wires for photomicrosensor (Vcc, GND, signal) 2 wires for motor (out1, out2)

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photomicrosensor on encoder board (EE-SY193 by omron^[1])



motor (Sub-Micro Plastic Planetary Gearmotor by Pololu^[2])



3 wires for photomicrosensor (Vcc, GND, signal) 2 wires for motor (out1, out2)

In total: 180 wires = 5 wires/pin x 36 pins CHI2020 22



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PoCoPo | Implementation







PoCoPo

User Study

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Study 1: Shape Prediction without Visual Information



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Study 2: Visual Size Acceptance Range

Please read our paper.



Study 1: Design & Setup







Study 1: Shapes Used in Study













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Study 1: Procedure



Set-1 (practice, not used for analysis) CHI2020 31

Set-3



Study 1: Results & Discussions

	Rectangle -	20	0	0	0	0	0	0	0	0
	Cylinder -	1	17	2	0	0	0	0	0	0
	Sphere -	0	0	14	5	0	0	0	0	0
÷	Circle -	0	0	0	20	0	0	0	0	0
bjec	Hemicylinder (upper) -	0	0	0	0	19	1	0	0	0
rue o	Hemisphere (upper) -	0	0	0	0	1	17	2	0	0
F	Semicircle (upper) -	0	0	0	0	0	0	20	0	0
	Hemicylinder (lower) -	0	0	0	0	0	0	0	18	1
	Hemisphere (lower) -	0	0	0	0	0	0	0	1	16
	Semicircle (lower) -	0	0	0	0	0	0	0	1	3
		Rectangle -	Cylinder -	Sphere -	- Circle Pre	- Hemicylinder (upper) -	p Hemisphere (upper) -	- Semicircle (upper) -	Hemicylinder (lower) -	Hemisphere (lower) -
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Study 1: Results & Discussions

	Rectangle -	20	0	0	0	0	0	0	0	0
	Cylinder -	1	17	2	0	0	0	0	0	0
	Sphere -	0	0	14	5	0	0	0	0	0
۲	Circle -	0	0	0	20	0	0	0	0	0
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	Hemicylinder (lower) -	0	0	0	0	0	0	0	18	1
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	Semicircle (lower) -	0	0	0	0	0	0	0	1	3
		Rectangle -	Cylinder -	- Sphere	- Circle Pre	p Di Hemicylinder (upper) -	o G Hemisphere (upper) -	t Semicircle (upper) -	Hemicylinder (lower) -	Hemisphere (lower) -







Study 1: Results & Discussions

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ť	Circle -	0	0	0	20	0	0	0	0	0
objec	Hemicylinder (upper) -	0	0	0	0	19	1	0	0	0
rue (Hemisphere (upper) -	0	0	0	0	1	17	2	0	0
⊢	Semicircle (upper) -	0	0	0	0	0	0	20	0	0
	Hemicylinder (lower) -	0	0	0	0	0	0	0	18	1
	Hemisphere (lower) -	0	0	0	0	0	0	0	1	16
	Semicircle (lower) -	0	0	0	0	0	0	0	1	3
		Rectangle -	Cylinder -	Sphere -	Circle	- Hemicylinder (upper) -	A Hemisphere (upper) -	- Semicircle (upper) -	Hemicylinder (lower) -	Hemisphere (lower) -
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Lowest prediction rate:

- Sphere ullet
- Tend to be confused with Circle
- P10:"Difficult to tell the difference between sphere and circle in rows."



Increasing the number of rows would improve prediction rates.



Study 1: Results & Discussions

	Rectangle -	20	0	0	0	0	0	0	0	0
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		Rectangle -	Cylinder -	Sphere -	Circle Circle	a Di Hemicylinder (upper) -	o Hemisphere (upper) -	n Semicircle (upper) -	Hemicylinder (lower) -	Hemisphere (lower) -

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Prediction rate (upper): 93.3% Prediction rate (lower): 83.3%

 Tendency to confuse Hemisphere (lower) & Semicircle (lower)

P5: "Difficult to distinguish the pin length with the palm base."

Not important to increase pin resolution for palm base

Palm base is not sensitive



Study 1: Results & Discussions

Rectangle -	20	0	0	0	0	0	0	0	0
Cylinder -	1	17	2	0	0	0	0	0	0
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Hemicylinder (upper) -	0	0	0	0	19	1	0	0	0
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	Rectangle -	Cylinder -	Sphere -	Circle	- Hemicylinder (upper) -	o Hemisphere (upper) -	- Semicircle (upper)	Hemicylinder (lower) -	Hemisphere (lower) -
	Rectangle - Cylinder - Sphere - Circle - Hemicylinder (upper) - Semicircle (upper) - Hemisphere (lower) - Semicircle (lower) -	Rectangle -20Cylinder -1Sphere -0Circle -0Hemicylinder (upper) -0Semicircle (upper) -0Hemisphere (lower) -0Semicircle (lower) -0Semicircle (lower) -0	Rectangle -200Cylinder -117Sphere -00Circle -00Hemicylinder (upper) -00Semicircle (upper) -00Hemisphere (lower) -00Semicircle (lower) -00Semicircle (lower) -00	Rectangle20000Cylinder1172Sphere0014Circle000Hemicylinder (upper)000Semicircle (upper)000Hemisphere (lower)000Semicircle (lower)000Semicircle (lower)1000Semicircle (lower)000Semicircle (lower)1000Semicircle (lower)000Semicircle (lower)000Semicircle (lower)000Semicircle (lower)000Semicircle (lower)000Semicircle (lower)000Semicircle (lower)000Semicircle (lower)Semicircle (l	Rectangle 20 0 0 0 Cylinder 1 17 2 0 Sphere 0 0 14 5 Circle 0 0 0 20 Hemicylinder (upper) 0 0 0 0 Semicircle (upper) 0 0 0 0 Hemisphere (lower) 0 0 0 0 Semicircle (lower) 0 0 0 0 Semicircle (lower) 0 0 0 0 Semicircle (lower) 0 0 0 0 Preter Image: Semicircle (lower)	Rectangle 20 0 0 0 0 Cylinder 1 17 2 0 0 Sphere 0 0 14 5 0 Circle 0 0 0 10 10 10 10 Hemicylinder (upper) 0 0 0 0 1 1 Semicircle (upper) 0 0 0 0 0 0 Hemisphere (lower) 0 0 0 0 0 0 0 Semicircle (lower) 0 0 0 0 0 0 0 Semicircle (lower) 0 0 0 0 0 0 0 Virus Jage	Rectangle 20 0 0 0 0 0 Cylinder 1 17 2 0 0 0 Sphere 0 0 14 5 0 0 Circle 0 0 0 0 1 17 Hemicylinder (upper) 0 0 0 0 1 17 Semicircle (upper) 0 0 0 0 0 0 0 Hemisphere (lower) 0 0 0 0 0 0 0 0 Semicircle (lower) 0 0 0 0 0 0 0 0 Semicircle (lower) 0 0 0 0 0 0 0 0 0 Semicircle (lower) 5 1 1 1 1 1 1 1 Semicircle (lower) 0 0 0 0 0 0 0 1 1 Semicircle (lower) 5 1 1 1 1 1	Rectangle 20 0 0 0 0 0 0 0 Cylinder 1 17 2 0 0 0 0 Sphere 0 0 14 5 0 0 0 Circle 0 0 0 20 0 0 0 Hemicylinder (upper) 0 0 0 0 1 17 2 Semicircle (upper) 0 0 0 0 0 0 0 0 Hemisphere (lower) 0 0 0 0 0 0 0 0 0 0 Semicircle (lower) 0 <	Rectangle 20 0

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PoCoPo

Applications

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Rendering Static Shapes



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c: trophy (concave)





Rendering Dynamic Shapes





Application: Rendering an object in VR Expanding/shrinking as a hamster beats.





Application: Rendering an object in VR Moving pins with the movement of a snake.





PoCoPo

Limitation & Future Work





"Slow" pin speed

"Small" number of pins

"Limited" display area

"Lack" of touch detection capability



"Slow" pin speed "Small" number of pins "Limited" display area

"Lack" of touch detection capability

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-> Visuo-haptic illusion^[2]







"Slow" pin speed

"Small" number of pins

"Limited" display area

"Lack" of touch detection capability



"Slow" pin speed

"Small" number of pins

"Limited" display area

"Lack" of touch detection capability -> Embed touch sensors into pins





PoCoPo

Conclusion



Contributions

- 1. Concept of handheld pin-based shape display
 - Realtime rendering of 2.5D shapes in hand by pin arrays
 - Providing skin contact sensation on user's hand in VR
 - in-based shape display, named PoCoPo Design of
 - ctuators & circuits so that they do not interfere with hand
 - mechanism
- of PoCoPo
 - dy 1: users can distinguish shapes with orage 88.5%
 - vsical size Study 2: users tend to feel visual size larger



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- 1. Concept of handheld pin-based shape display
 - Realtime rendering of 2.5D shapes in hand by pin arrays
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- 2. Design of handheld pin-based shape display, named PoCoPo
 - Miniaturization: placing actuators & circuits so that they do not interfere with hand
 - Non-backdrivability: worm-gear mechanism
- 3 Evaluations to understand the capability
 - Study 1: users can distinguish shapes with prage 88.5%
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Contributions

- 1. Concept of handheld pin-based shape display
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 - Miniaturization: placing actuators & circuits so that they do not interfere with hand
 - Non-backdrivability: worm-gear mechanism

3. Evaluations to understand the capability of PoCoPo

- Study 1: users can distinguish shapes with average 88.5%
- Study 2: users tend to feel visual size larger than physical size





$\mathsf{CHIP}_{\mathsf{2020}}\mathsf{POCOPO}$

Handheld Pin-based Shape Display for Haptic Rendering in Virtual Reality

The University of Tokyo

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www.shigeodayo.com/pocopo.html

*The first two authors contributed equally to this work.